MATHEMATICAL MODELS OF THE INPUT SIGNALS IN AN ADAPTIVE TELEMETERING SYSTEM

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Abstract

Some mathematical models of the input signals in an adaptive telemetring system are developed for the purpose of the redundancy reduction of the measuring data or the "volume information reduction", i.e., for the construction of systems with data compression. In the model, the signals from 250 airship telemetering elements, divided into six blocks, are processed following the signals activity. The application of the model for the measuring data flow allowed increasing the number of measurement channels at the existing transmission capacity of an optical channel (25Mbit\s) for the "Agat" series by a factor of 1.7-2.

1. Introduction

The development of the mathematical models of signals from the sensors of various values of an airship telemetry system is intended to model the measuring data flow for the purpose of the redundancy reduction of the measuring data or the "volume information reduction", i.e., the construction of systems with data compression.

90% of expenses on the obtaining and processing of measuring data in the radio-telemetering systems fall on the redundant information [1]; therefore, the problem of the data compression is very urgent. This work examines 250 airship telemetering signals divided in six blocks following the signal activity.

2. Analysis of signal blocks

The presented typical signals (Figs. 1-6), two from each block, are divided into six blocks with respect to activity (Table 1).

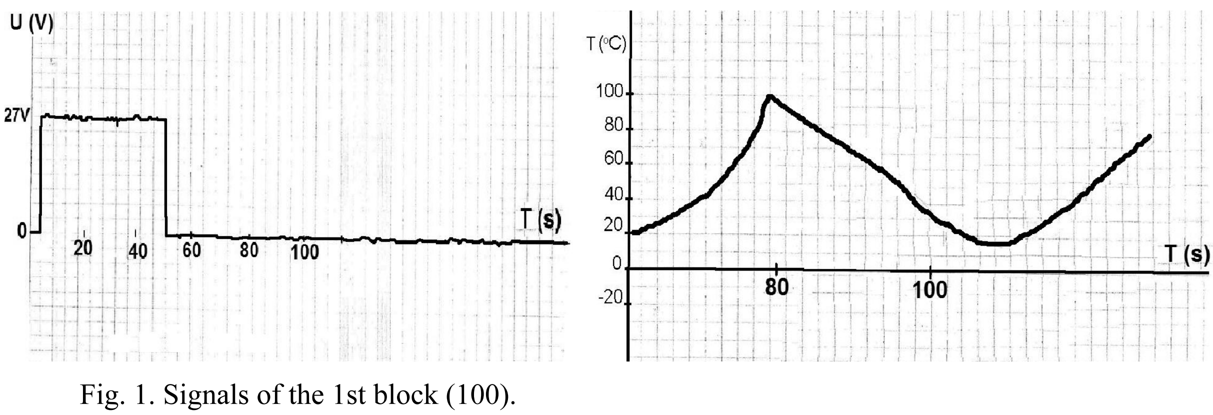

Fig. 1. Signals of the 1st block (100).

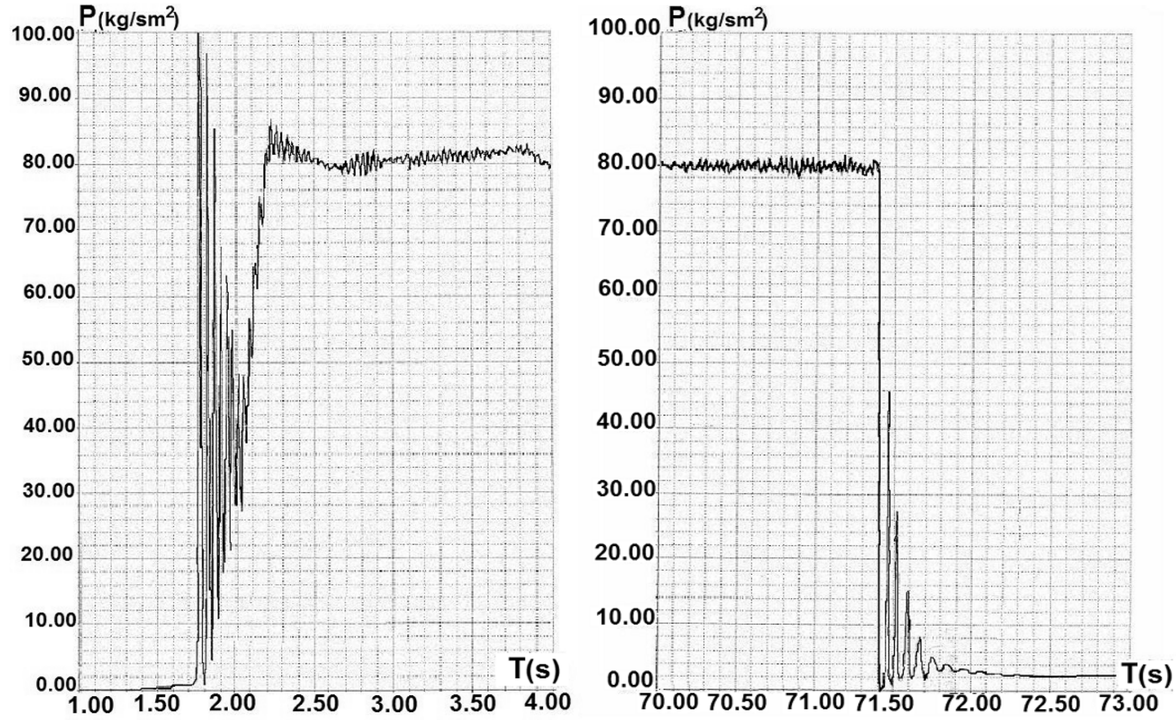

Fig. 2. Signals of the 2nd block (50).

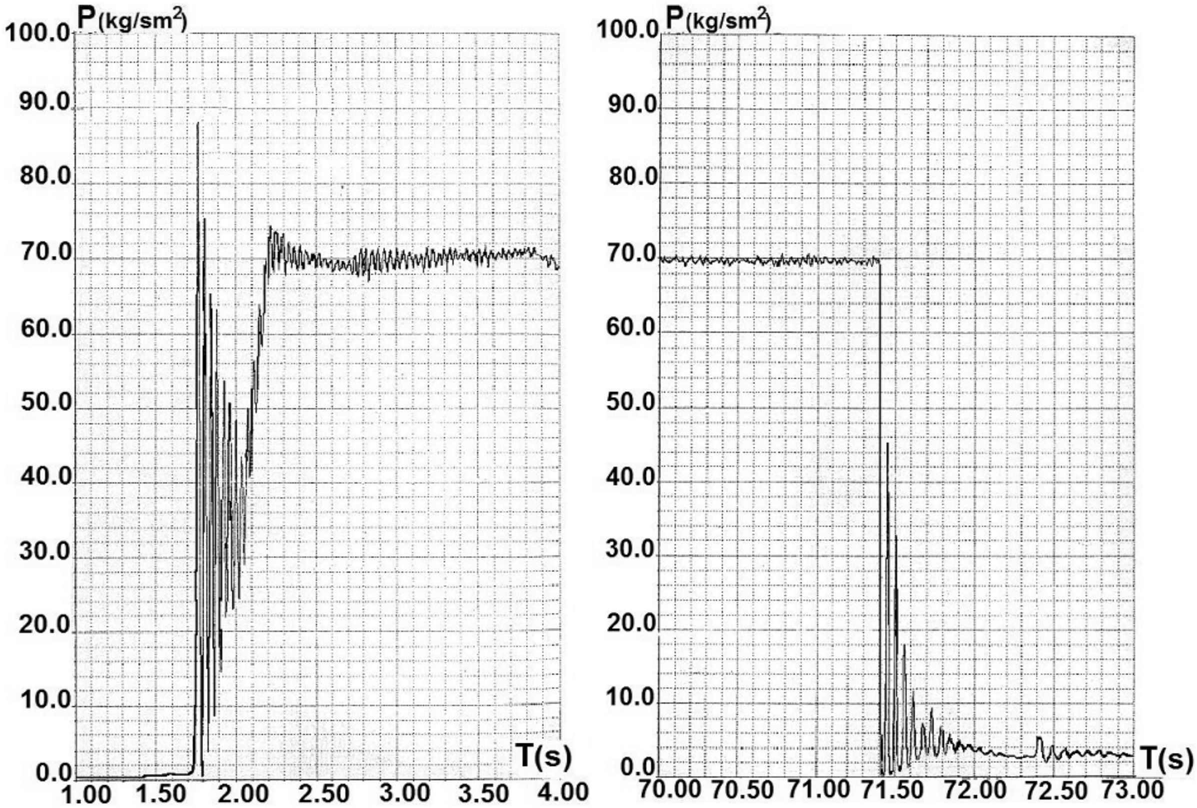

Fig. 3. Signals of 3d block (50).

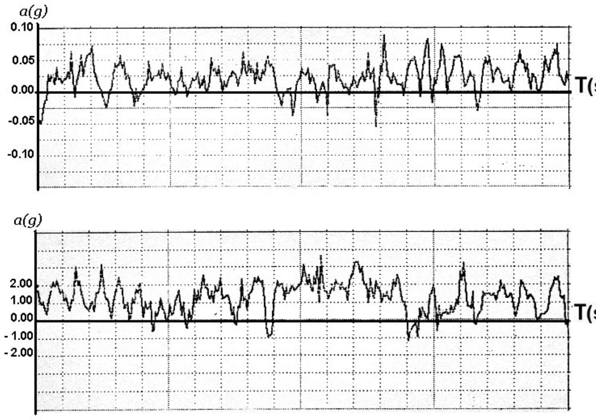

Fig. 4. Signals of the 4th block (20).

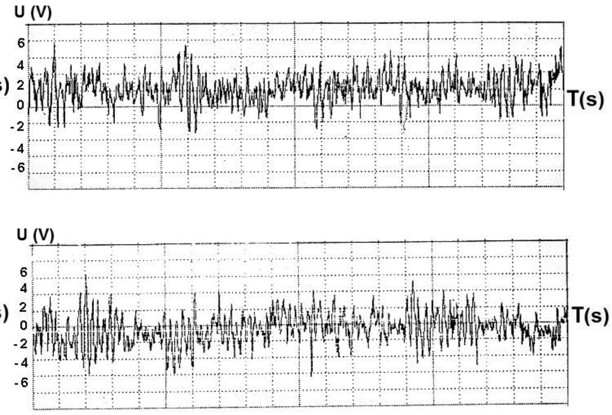

Fig. 5. Signals of the 5th block (20).

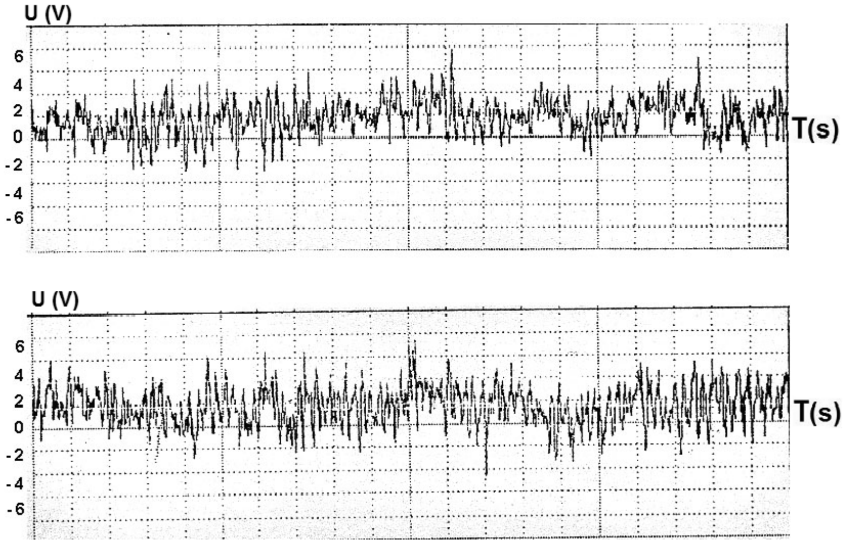

Fig. 6. Signals of the 6th block (10).

A part of signals of the given group from common flow was reduced in the last column $P_i = F_iN_i/(F_1N_1+F_2N_2+F_3N_3+F_4N_4+F_5N_5+F_6N_6)\cdot 100\%$, where F_i is the sampling frequency of the 1st block signals, N_i is the number of signals.

Table 1.

Block number	Sampling frequency, Hz	Number of signals in block	Part of block in the total flow, %
1	25	100	2.1
2	75	50	3.4
3	300	50	13.5
4	1000	20	18.0
5	2000	20	36.0
6	3000	10	27.0
Total		250	100

The part of signals of the first and second block (in total 150 signals) is 5.5% (Table 1).

Evidently, it is not reasonable to compress the signals of these groups. Only prefiltration may be used on the transmitting side.

The part of the signals of the third block is also insignificant, 13.5% only. It is reasonable to divide this block into two parts. It is necessary to select those in the first part, where the compressibility effect is maximal, and to transfer the other signals by means of uniform time discretization (UTD).

The analysis of the signals of blocks 3-6 shows that it is possible to use models of two types for their description:

- The first type represents the sum of the deterministic process (slowly varying constant) and of the high-frequency fluctuation close to harmonic fluctuation with the low-frequency envelope (curve in Fig. 3).
- The second type represents the random process (Figs. 4 – 6).

3. Description of signals of the first type

The model of such signals is sufficiently simple: it is the sum of the deterministic component and vibration harmonic. The deterministic component is described by the polynomial of the 1 or 2 degree, including (if necessary) the use of spline-approximation [2].

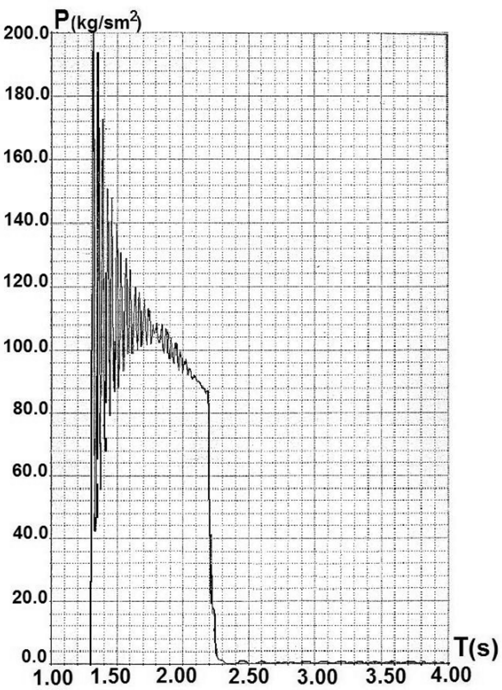

Fig. 7. Signals of the 3rd block, initial section.

The following function can serve the exemplary construction of the mathematical model for the signals of the 3rd block in the initial section (Fig. 7)

$$f(t)=\begin{cases} 0, & 0\le t<1.3 \\ Ax^2+Bx+C + D\exp(\alpha t)\sin(\omega_O t), & 1.3\le t<2.18 \\ Ex^2+Fx+G + H\sin(\omega_O t), & 2.18\le t<2.35 \\ I\sin(\omega_O t), & t\ge 2.35, \end{cases}$$

where A = 39.8; B = 107.4; C = 40.9; D = 35000; E = 8120; F = 37208; G = 42610.5; H = 1; I = 1; α = -4.5 1/s; ω_O= 175 1/s.

The envelope curve is described either as the deterministic component (e.g., the signal in Fig. 7) or as the low-frequency random process (Fig. 8) subject to the signal mode. The correlation function type is not of considerable importance in this case, because the low-frequency random process quality does not influence the compression characteristic.

The activity of the signals (the rate of signal change and its derivates) of the 1st block varies considerably in time as follows from the presented data. These signals have two clearly defined portions of the peak of activity, as a rule, in the beginning and in the end of experiment. Therefore, the initial phase is more active, and the system capability should be defined first of all for this period.

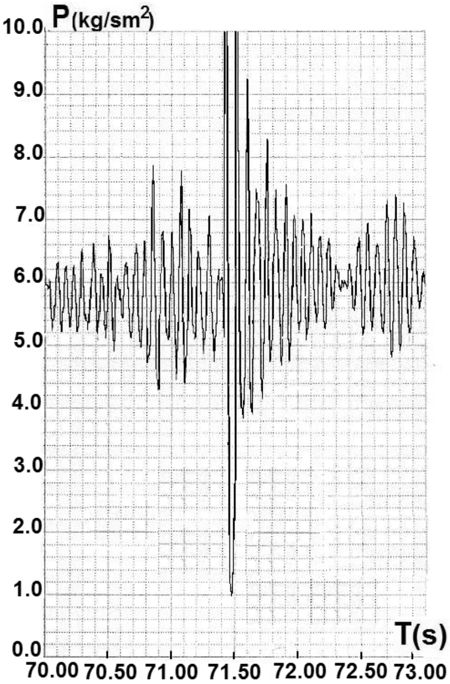

Fig. 8. Signal of the 1st block, the end portion.

The signal activity decreases significantly in the middle of experiment (approximately by an order) and the system capability is not used to a considerable degree. However, this reserve is extremely necessary for a system functioning in an emergency when the activity of signals and their value increase sharply. Systems with data compression, unlike UTD systems, allow transferring the most valuable information in an emergency. For this purpose, other methods can be used in addition to the most adaptive digitization (commutation), for example, the increase of digitizer setting in the irresponsible channels or their blackout (by software).

It is efficient to use aperture algorithms as well as for signals of the second type, if the signals containing the low-frequency deterministic component cannot be presented as a harmonic function.

4. Description of signals the second type

The analysis of signals (Figs. 4-6) showed that signals of the second type can be described as stationary random processes with correlation functions:

$$R_1(\tau) = \exp(-\alpha|\tau|)\ [1+ \alpha|\tau| + \alpha^2\tau^2/3,$$

$$R_2(\tau) = \exp(-\alpha^2\tau^2).$$

The spectral densities of such signals are, respectively,

$$S_1(\omega) = \frac{16\alpha^5\delta^2}{3(\alpha^2+\omega^2)^3} \text{ and } S_2(\omega) = \frac{\delta^2}{\alpha}\sqrt{\pi}\exp(-\omega^2/(4\alpha^2)) .$$

See below the estimation of signal correlation functions for each block.
The fourth block:

$$R_1(\tau) = \exp(-340|\tau|)\,[l + 340|\tau| + 340\tau^2/3,$$
$$R_2(\tau) = \exp[-(175\tau)^2]$$

The fifth block:

$$R_1(\tau) = \exp(-680|\tau|)\,[l + 680|\tau| + 680\tau^2/3,$$
$$R_2(\tau) = \exp[-(350\tau)^2]$$

The sixth block:

$$R_1(\tau) = \exp(-1020|\tau|)\,[l + 1020|\tau| + 1020\tau^2/3,$$
$$R_2(\tau) = \exp[-(520\tau)^2]$$

The signal series are stroked by a high frequency disturbance, as a rule. Therefore, such input signals should be subjected to prefiltration.

5. Conclusions

The mathematical model of signals from sensors of various values of an aircraft telemetry system was used for flow modeling of the aircraft measuring data and in the “Agat” instrumentation management systems [3] for the purpose to reduce the measuring data redundancy for the construction of an adaptive telemetering system with data reduction.

The application of the model for the measuring data flow allowed increasing the number of measurement channels at the existing transmission capacity of an optical channel (25 Mbit/s) for the “Agat” series by a factor of 1.7 – 2.

References

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